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# AN ALIGNMENT CHART FOR UPPER WIND VECTOR COMPUTATIONS INVOLVING LARGE HORIZONTAL DISTANCES

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The standard method for getting winds aloft data from successive pibal or rawin distance-out and elevation-angle determinations fails when the horizontal distance involved is greater than a few miles, owing to the limitation imposed on the graphical wind vector computation by the size of the plotting boards now in use. Since the trend in wind soundings is to greater heights, and consequently to greater horizontal distances, alternatives to the graphical technique are of interest. Direct calculation of the vector components is possible but cumbersome. A wind vector calculation for use at great horizontal distances, when the difference between successive azimuths is small, will be described, together with an alignment chart for performing the computations.

When the angular difference between successive azimuth observations on a balloon or target is small, less than 5.8 degrees, the sine and the radian measure of this angle differ in at most the fourth significant figure. Referring to figure 1, this means that, with an error of less than one percent,

$$d_1 \cos \alpha = d_1$$

leading to the following simple formulas from which, given successive horizontal distances out and azimuths, the wind vector can be found:

$$\tan \beta = \frac{d_t \sin \alpha}{|d_2 - d_1|} \tag{1}$$

$$D = \frac{d_t \sin \alpha}{\sin \beta} \tag{2}$$

Here $d_t$ is the smaller of $d_1$ and $d_2$, the horizontal distances out at successive readings, $\alpha$ is the difference between successive azimuths, $\beta$ is the smaller of the two remaining angles of the triangle, and $D$ is the absolute value of the wind vector. If $d_1 \cos \alpha$ is substituted for $d_1$ in the denominator of equation (1), the equations will be exact. The greatest error which can arise because of the approximation amounts to about .1° in $\beta$ and .1 percent in $D$.

Figure 2 is an alignment chart, of the set-square index type, for solving equations (1) and (2). As in the example included with the figure, $d_1$ or $d_2$, whichever is smaller, and $\alpha$ are first aligned on scales I and II, most readily by means of a transparent straightedge. A perpendicular to this line through $|d_2-d_1|$ on III passes through $\beta$ on the *upper* scale of IV, and a second perpendicular through $\beta$ on the *lower* scale of IV passes through $D$ on III. Practically, an ordinary drafting triangle, slid along the straightedge,

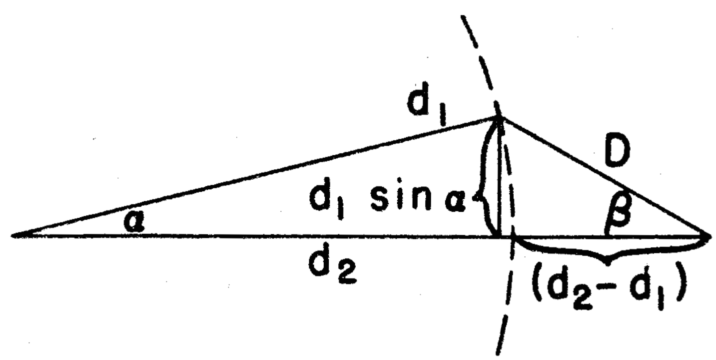


FIGURE 1.—Triangle to be solved in determining the wind vector $D$, given successive horizontal distances out, $d_1$ and $d_2$, and difference, $\alpha$, between successive azimuths.

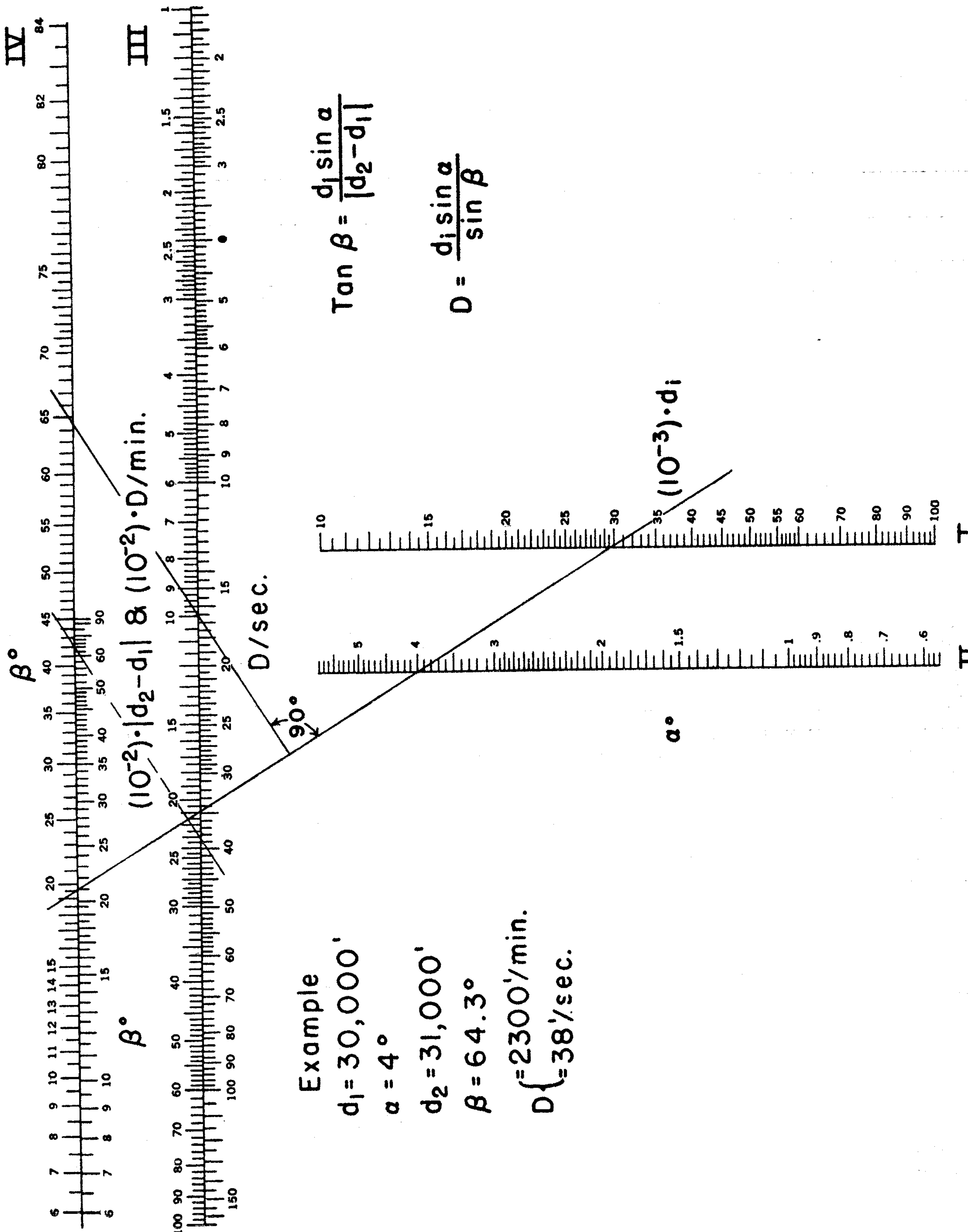


FIGURE 2.—Alignment chart for upper wind vector computations involving large horizontal distances. Based on equations (1) and (2).

gives these perpendiculars quickly. The true wind direction is obtained by combining $\beta$ with the second azimuth, $A_2$, in one of four possible ways, according to the following rules:

If $A_1$ and $A_2$ are successive azimuth observations

a) $A_2-A_1>0$
   1) $d_2>d_1$, direction$=A_2+\beta\pm180°$
   2) $d_2<d_1$, direction$=A_1-\beta$

b) $A_2-A_1<0$
   1) $d_2>d_1$, direction$=A_2-\beta\pm180°$
   2) $d_2<d_1$, direction$=A_1+\beta$

If values of $D$ are read from the upper scale of III, they will be in distance units per minute (assuming a one-minute interval between readings). The lower scale of III converts this to units per second. Thus the calculation may be carried out in any distance units which are convenient. As an example, these values are given:

$$A_1=239.1°$$
$$A_2=243.1°$$
$$\alpha=A_2-A_1=+4°\ (>0)$$
$$d_1=30{,}000 \text{ ft.}$$
$$d_2=31{,}000 \text{ ft.}$$
$$|d_2-d_1|=1{,}000 \text{ ft.}$$

Following the light guide lines on the figure, it is found that:

$$\beta=64.3°$$
$$\text{direction}=A_2+\beta-180°=127.4°$$
$$D=2{,}300 \text{ ft./min.}=38 \text{ ft./sec.}$$

These calculations can, of course, be done on the ordinary slide rule. Apart from the intrinsic interest possessed by this form of nomogram, its main advantages are speed and simplicity. Thus, the calculation requires three operations on the alignment chart, but a minimum of seven on the slide rule. Furthermore, no special attention need be paid to the location of the decimal point, since each scale is designed only for a particular range; and consequently there is no danger of applying the chart to values of $\alpha$ or $d_i$ for which the formulas are not valid. The chart can be extended down to arbitrarily small values of $\alpha$ by (mentally) dividing scale II by an appropriate power of ten, and multiplying scale I by the same power. In the example given, for instance, values of $\alpha=.4°$ and $d_1=300{,}000$ ft. could have been used, with the same result.

Practically speaking, the horizontal distance over which the formulas will give a reasonably good answer is bounded on the upper side by the fact that above 50 miles or so the curvature of the earth introduces an increasingly important error into the distance-out determination. Otherwise, this chart is a valid, convenient alternative to present methods. Its accuracy depends mainly on the size of the scales and in this respect equals that of a small slide rule, which is ample for the problem. Alignment charts have not been applied in routine meteorological calculation to an extent which appears to be consistent with their popularity and proved utility in other fields. One of the main reasons for this presentation is that it is a good example of the advantages of speed and conciseness available through the use of these diagrams.